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Method and Algorithm for the Insertion of New Transmitter Into Existing Frequency Plans for Radio Communication Services

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Abstract: This paper deals with the procedure of new transmitter insertion into the existing Plan, including results of transmitter insertion simulation with software support developed for the proposed algorithm. The same procedure can also be applied for other radio communication services using the corresponding plans and technical requirements databases (minimum field, protection ratio, etc.). The proposed algorithm ensures an efficient and economical use of radio frequency spectrum.

Keywords: Radio frequency allotment plan, radio frequency assignment plan, frequency spectrum, transmitter's insertion.

1 Introduction

The establishing of Radio Frequency Allotment and Assignment Plans to be used for various radio communication services is, by all means, an extremely complex procedure. First and, at the same time, basic aim of establishing the mentioned Plans is twofold: to fulfil the existing needs, as well as to take into account overall future needs, both for the existing services and for new services. During this multifaceted process, it is necessary to constantly bear in mind the necessity of an efficient and economical use of radio frequency spectrum.

However, even if all basic factors are applied in the aforementioned procedure, it often happened that new transmitters operating in the same service and under the same technical conditions had to be introduced into these Plans.

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The aim of this paper is to present one method of introducing a new transmitter into the existing Plan. The proposed algorithm may be used for any of radio communication services, and here the procedure will be shown for the broadcasting service (television).

The concept of this paper is to start with technical requirements and parameters to be applied in the process of new transmitter insertion, followed by a description of insertion procedure where, in the scope of a general insertion procedure, the proposed algorithm is first presented and then general and special calculations of protection ratio are given. Finally, the results of simulation with software support based on the proposed algorithm are given in two characteristic exercises of specific transmitters insertion.

2 Technical Conditions and Parameters

The consideration of each and every case of introducing a new transmitter into the existing Plan has to be in line with the procedure already applied during the establishing of the relevant Plan [1]. Therefore, it is necessary for the new transmitter to have the same information and data applied as for already planned transmitters, i.e.

- Geographical Coordinates (latitude and longitude) of the Transmitting Antenna Site;
- Site Altitude Above Sea Level;
- Antenna Directivity;
- Polarization;
- Antenna Height Above Ground Level;
- Assigned Frequency (or Frequency Channel);
- Frequency Stability;
- Class of Emission and Bandwidth;
- Maximum Effective Radiated Power (E.R.P)
- Table of antenna attenuation (for directive antennas) presented as attenuation (dB) vs. azimuth (deg), generally for 10 arc degree step, but also less.

Antenna height above ground level is to be understood as the height of the antenna system radiation centre, when the antenna system consists of several bays.

Certain technical conditions and parameters, stipulated by the international and national standards and recommendations are clearly defined in the frequency plan establishing process. These conditions and parameters have also to be used in the case of introducing new transmitter into the existing Plan. It should be underlined that these factors are dependent of the radio communication service type.

In the situation regarding broadcasting service, the following parameters are to be considered:

1. Minimum field strength (MFS) [2] is the field strength value produced by the transmitter at the border of its service area. This value is related to frequency band, and is shown in the Table 1.

Table 1. Minimum filed strength in relation to frequency bands

Frequency band (ITU)	VHF		UHF	
Frequency Band (EBU)	I	III	IV	V
Frequencies (MHz)	47-68	174-230	470-602	602-790
Channels	2,3,4	5-12	21-34	35-69
Minimum field strength (dB(μV/m))	48	55	65	70

2. Protection ratio is defined as the ratio between usable and interfering field strength in the same radio channel and hereinafter will be marked as IOF. Table 2 lists these protection ratios both for steady and for tropospheric interference, with non-precision frequency offset from 0 to 12 with transmitter stability $\pm$500 Hz [3]. The use of frequency offset is a very valuable solution, as this method enables the examination of new transmitter introduction into the Plan by means of choosing the most suitable vision carrier frequency offset of new transmitter in relation to planned transmitters vision carrier frequency. This method is applicable both in VHF and UHF bands.

Table 2. Protection ratio of wanted signal to interfering signal in the same channel relating to the frequency offset, both for tropospheric and steady interference

Frequency offset	0	1	2	3	4	5	6	7	8	9	10	11	12
IOF for tropo. interference (dB)	45	44	40	34	30	28	27	28	30	34	40	44	45
IOF for steady interference (dB)	52	51	48	44	40	36	33	36	40	44	48	51	52

3. Another crucial parameter is defined as the protection ratio between usable and interfering field strength operating in the adjacent radio channels. The values of this factor are different for upper and for lower adjacent channel [3], i.e. one value is for N+1 channel, and another for N-1 channel, where N is wanted transmitters channel. As previously, values also differ for tropospheric and steady interference and are applicable both for VHF and UHF bands (Table 3).
4. Protection ratio between usable and interfering field strength operating in the radio channels separated by nine channels, N+9 channel, and N-9 channel, where N is wanted transmitters channel, is also significant [3]. As earlier, values also differ for tropospheric and steady interference. However, this ratio is applicable for UHF band only (Table 3).

Table 3. Protection ratio of wanted signal to interfering signal for various channel spacing for tropospheric and steady interference

Channel spacing	$N+1$	$N-1$	$N\pm9$
Protection ratio for tropospheric interference (dB)	-12	-9	-1
Protection ratio for continuous interference (dB)	-2	$+1$	$+6$

5. Interferences may also occur when the channel spacing is equal to five channels (N5). However, there are no exact protection ratio numerical values for this interference type. Protection is considered as satisfactory only in the case when there is no overlapping of service areas.

3 Insertion Procedure

Certain calculations aimed at finding the possibility of the insertion of new transmitter into the existing Plans are necessary. To perform these calculations, particular databases, either existing or newly formed, are required. It is necessary to have access to:

- Allotment (Assignment) Plan related to the specific radio communication service and/or frequency band and the country concerned (National Plan).
- Allotment (Assignment) Plans concerning other countries (neighbouring but also others) whose transmitters may affect the inserted transmitter or may be affected by this transmitter.
- Digital Terrain Model (DTM),or, in the case that such database is not available, information of effective antenna height for the transmitting antenna site tabulated for at least 10 degrees of true azimuth.
- Evaluation software or evaluating electromagnetic field according to the relevant ITU-R Recommendation [4]

In the evaluation process it is necessary to use data from relevant national and other databases (Plans) relating to transmitters which may affect the inserted new transmitter or which may be affected by it.

Figure 1 presents arbitrary chosen transmitters according the existing plans related to new transmitter (B) intended to be inserted into the Plan.

3.1 General algorithm for new transmitter insertion

General algorithm for inserting the new transmitter into the Plan is prepared in accordance with technical requirements and parameters. This algorithm contains step-by-step calculation of insertion on:

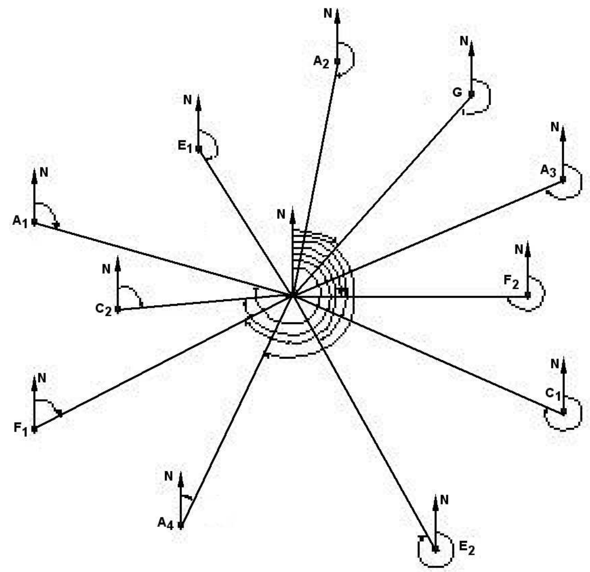

Fig. 1. Position of new (inserted) transmitter in relation to planned transmitters.
A_n Existing and planned transmitters operating on the same channel, where $n = 1, 2, \ldots$
C_n Existing and planned transmitters operating on adjacent channel, $N + 1$ where $n = 1, 2 \ldots$
E_n Existing and planned transmitters operating on adjacent channel, $N - 1$ where $n = 1, 2, \ldots$
F_n Existing and planned transmitters operating on $N + 9$ channel where $n = 1, 2, \ldots$
G_n Existing and planned transmitters operating on $N - 9$ channel where $n = 1, 2, \ldots$

- the same channel,
- upper and lower adjacent channels,
- five channels above and five channels below the newly chosen channel,
- nine channels above and nine channels below the newly chosen channel.

General algorithm is presented in Figure 2

3.2 General insertion evaluation

The evaluation is to be done successively for all relevant transmitters. In the first step, and using parameters from the relevant databases, it is necessary to determine mutual positions of new and existing transmitters. The said positions are determined by:

- distance between two transmitters
- true azimuth from inserted transmitter to the existing one
- true azimuth from existing transmitter to the inserted (counter azimuth)

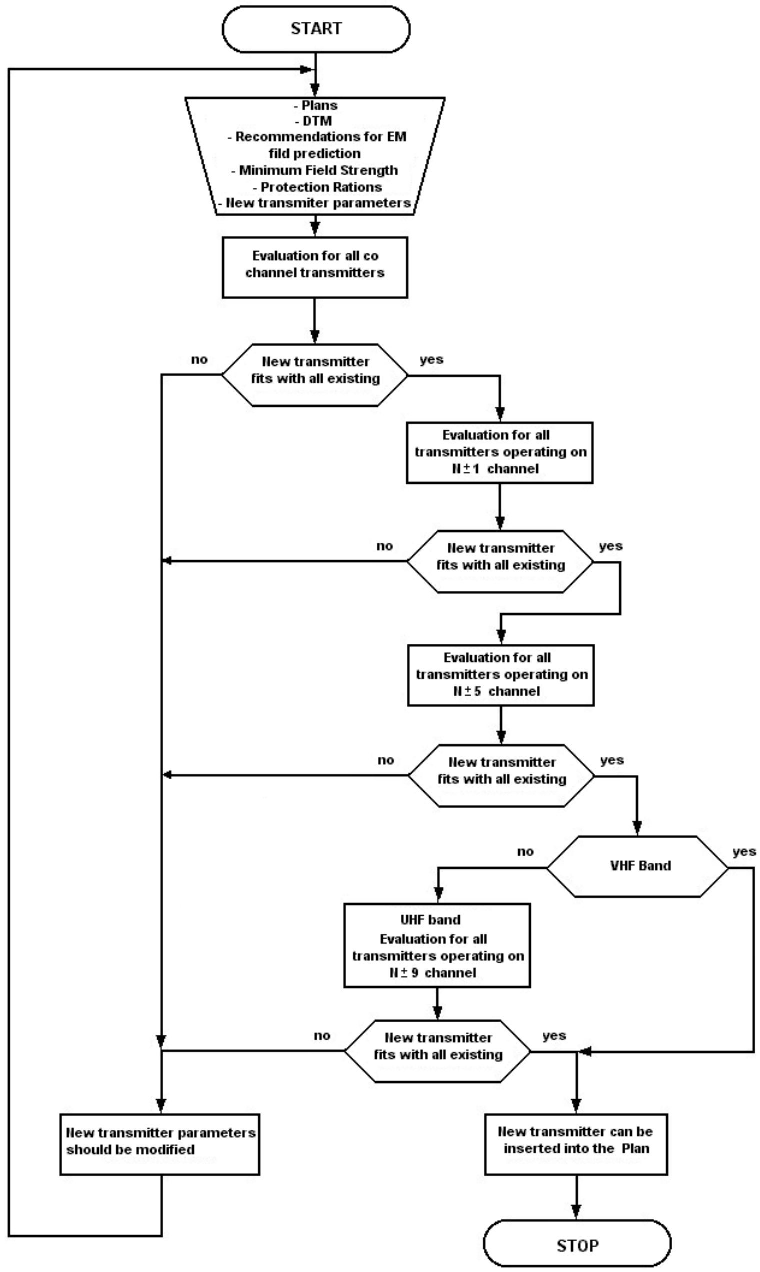

Fig. 2. General algorithm for new transmitter insertion analyzing.

Information on azimuths is necessary for obtaining correct values of effective antenna height, as well as effective radiated power in the given direction, using antenna radiation pattern.

Mutual positions of transmitters is shown in Figure 3, where levels of electromagnetic fields produced by both transmitters are also presented.

Values are labelled as follows:

- MFS- minimum field strength (for 50% of time and 50% of locations) at the edge of service area to be protected
- PR- protection ratio of the field strengths for wanted signal to the interfering signal on the same channel, from $N \pm 1$ channel and from $N \pm 9$ channel
- ISA- field strength of interfering signal from the existing transmitter to the inserted transmitter (1% of time and 50% of location) [1]
- ISB- field strength of interfering signal from the inserted transmitter to the existing one (1% of time and 50% of location) [1]
- AB- distance between two transmitters.

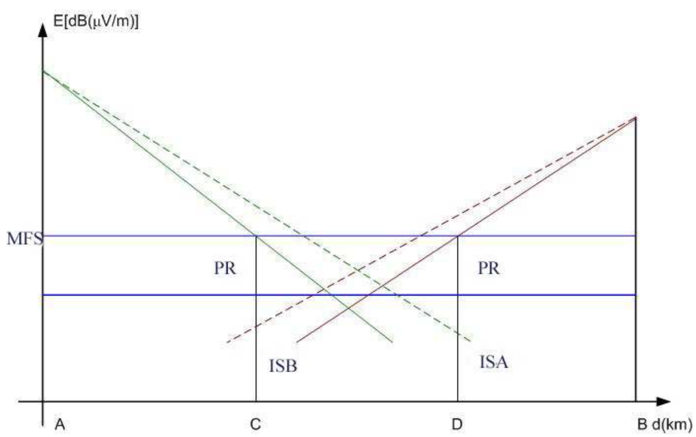

Fig. 3. Mutual positions of the existing and newly inserted transmitters with elements significant for evaluation.

The first step is to determine the distance on which the existing transmitter produces the usable field strength (MFS). [5] This distance is marked as AC and its end represents the bordering point of the existing transmitter service area in given azimuth.

The second step is to determine the distance on which the newly inserted transmitter produces the usable field strength (MFS). This distance is marked as BD and its end represents the bordering point of the inserted transmitter service area with specified parameters in given azimuth.

If the ratio of these spacing is

$$AB - AC < 0 \quad \text{or} \quad AB - BD < 0$$
$$AB - AC < BD \quad \text{or} \quad AB - BD < AC$$

it means that the service area of one transmitter is overlapping the service area of another transmitter. Consequently, there is no point in continuing evaluation as it is clear that the new transmitter operating on given frequency and with given effective radiated power does not fit into the Plan. Possible solutions are either to change the proposed frequency channel or to modify (decrease) the specified power.

If the distance ratio is different then above, i.e. if

$$AB - AC > BD \text{ and } AB - BD > AC$$

the evaluation shall continue.

The next step is to calculate the field strength (for 1% of time and 50% of locations) produced by interfering signal of the new transmitter taking into account the effective radiated power in the direction towards the existing transmitter at the edge of service area of the existing transmitter (point marked with C).

a) Calculated field strength of the new transmitter interfering signal is

$$ISB <= MFS - PR$$

This is to be so interpreted that the new transmitter using relevant radiated power and its other selected parameters does not produce harmful interference in the service area of the existing transmitter and the evaluation can go on.
Now it is required to find out if the conditions (in the point D) of the existing transmitter interfering signal field strength at the edge of new transmitters service area fulfil the criteria

$$ISA <= MFS - PR$$

If this condition is satisfied, this means that there are no reciprocated interferences between the existing and the new transmitter.
Evaluation is to be continued with other transmitters significant, according to previously listed criteria, for inserting the new transmitter into the Plan.
On this protection ratio calculation occasion, the best offset value (IOF) of new transmitter is to be taken and its value shall be introduced as relevant parameter into the Plan.

b) Calculated field strength of the new transmitter interfering signal is

$$ISB >= MFS - PR$$

If this case occurs, the sufficient protection from the new transmitter is not reached, in spite of the satisfactory choice of IOF. This situation may be solved by using protection due to different polarization [6], i.e. to implement vertical polarization for the new transmitter. If the condition

$$ISB < MFS - PR + 18$$

is fulfilled, the new transmitter is to be inserted into the Plan with vertical polarization and relevant offset. The evaluation can be continued with new parameters. If the above mentioned condition is not fulfilled, i.e. in the case that

$$ISB > MFS - PR + 18$$

there is no possibility of inserting the new transmitter into the Plan, even with vertical polarization. In such case, the entire evaluation shall start from the very first step but, of course, with entirely different parameters for the new transmitter which is intended to be inserted into the Plan Following the previous evaluation, the relevant algorithm is given in Figure 4.

General algorithm is presented in Figure 2

It should be noted that the above mentioned evaluation is to be performed in its entireness for all significant transmitters which means:

- for all co-channel transmitters,
- for all transmitters at adjacent channels, $N \pm 1$,
- for transmitters operating at $N \pm 5$ channels,
- for transmitters operating at $N \pm 9$ channels.

In the case of co-channel the protection ratio is to be chosen bearing in mind the best offset value, IOF. In all other cases protection ratio is fixed as it was stated earlier.

3.3 Particular calculation

Previously explained calculating method is based on the assumption that service areas of two transmitters are closest in the line AB. In certain number of cases this is a justified assumption particularly in the case when there are directional antenna

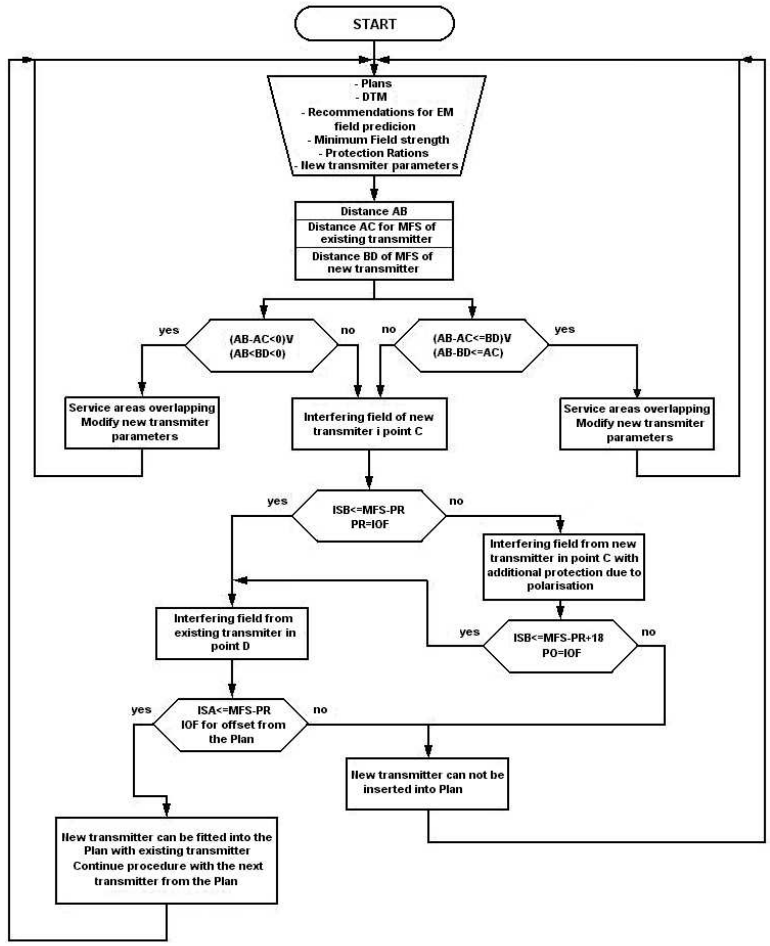

Fig. 4. Algorithm for co channel transmitters analyzing.

patterns in both cases and their directions do not have cross-section. The mentioned method is also applicable for the transmitters located in the plain and having non-directional (omni directional) antenna patterns. Consequently, the service areas are circularly shaped and minimum distance remains on the same direction AB.

On the other hand, in the case of hilly and mountainous terrains, the service area is not regular by shaped even in the case of non-directional antennas. [7] Service area contour is irregular due to the terrain configuration, which affects field strength calculation and, subsequently, the value of distance for minimum usable field strength. [7] Of course, the irregular service area shape is also a consequence of the directional antenna pattern.

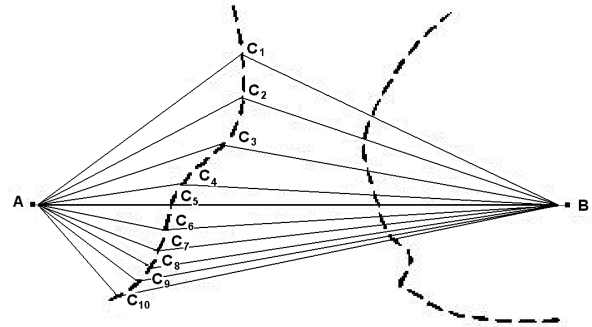

Fig. 5. Points on the existing transmitter service area border, used for evaluation.

Irregular service area samples are presented in Figures 5 and 6. The points significant for calculations are also shown. As it was said before, the service area contour may be the result either of the directional antenna pattern or, in the case of non-directional pattern, of terrain configuration impact, or of both.

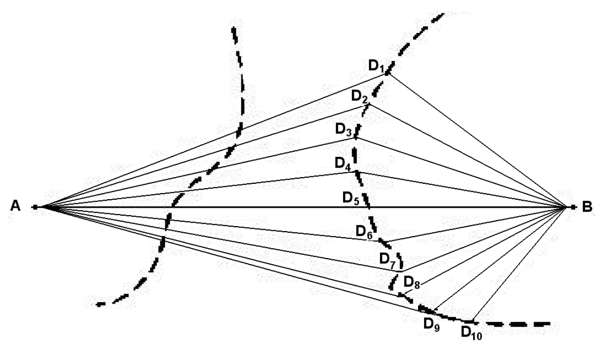

Fig. 6. Points on the new transmitter service area border, used for evaluation.

In order to be positive that all possible cases are taken into account, it is advisable to perform calculation for several points in service areas:

- from point A of the existing transmitter in the sector about 90 wide degrees relating to the AB direction (towards new transmitter)
- from point B of the new transmitter in the sector about 90 wide degrees relating to the BA direction (towards existing transmitter)
- in the directions of azimuth increment of 10 degrees (or less)

The evaluation itself is identical with the described general calculation above, as far as both elements and procedures are concerned.

The procedure of inserting new transmitter into the Plan is reliable and obtained results are satisfactory. Of course, the reliability is highly dependent of data accuracy and of algorithm used for field strength calculation.

4 Results of Algorithm Applications

Hereinafter two algorithm applications exercises are presented.

Exercise 1

Insertion of new transmitter with following parameters:

Transmitting site name	Aleksinac
Geographical coordinates	43N3207 21E4244
Altitude (mASL)	180 m
Antenna height (AGL)	135 m
Antenna pattern	directional, 180/230 degrees
Frequency channel for evaluation	39 (615,250 MHz)
Maximum effective radiated power	10W, 100W, 1kW, 100kW, 150kW

This exercise is made for various powers of new transmitter intended for insertion into the existing Plan.

It is valuable to note the following:

1. The number of transmitters significant for the insertion of new transmitter is increasing with the increase of the new transmitter's power.
    - For 10 W of new transmitters ERP 5 transmitters is to be taken into account.
    - For ERP between 10 W and 1 kW this number is 6.
    - For 10 kW of new transmitters ERP 8 transmitters is to be taken into account.
    - For 100 kW of new transmitters ERP 9 transmitters is to be taken into account.
    - For 150 kW of new transmitters ERP 14 transmitters is to be taken into account.
2. New transmitter has to be with vertical polarisation.

When the effective radiated power is increased, it is necessary to modify offset value in order to reduce protection ration and to ensure that new transmitter will fulfill the condition required.

It is also necessary to take care of offset while vertical polarization is implemented.

When the power modification is made with small increment (e.g. 50W) using the successive calculation, the result for power of 124,450 kW is obtained as upper power limit for insertion of this transmitter into the Plan.

Finally, the result of the algorithm is that the new transmitter can be inserted in the Plan with the following parameters:

ERP	124.450 kW
Polarization	vertical
Offset	5

If the power below the mentioned value is applied, insertion is possible under other conditions evident from the computer print-out.

Exercise 2

Insertion of new transmitter with the following parameters:

Transmitting site name	Vršac
Geographical coordinates	45N0720 21E1956
Altitude (mASL)	366 m
Antenna height (AGL)	20 m
Antenna pattern	directional, 215/305 degrees
Frequency channel for evaluation	46 (615,250 MHz)
Maximum effective radiated power	0.5 kW

As presented in the calculation, 14 transmitters in total are significant for insertion of new transmitter into the Plan:

- 7 from Serbia and Montenegro
- 3 from Hungary
- One each from Bulgaria and Bosnia and Herzegovina

Eleven transmitters are co-channelled, one each on upper and lower adjacent channel and one on nine channels lower.

For 10 channels the valuation shows that frequency offset is to be used in order to enable the new transmitter insertion into the Plan.

Another calculation result proves that with three existing transmitters the new one can be inserted with vertical polarization. Out of these three cases, in two cases the frequency offset is not important, but for the remaining one offset should be 3.

The result of the algorithm is that the new transmitter can be inserted in the Plan with the following parameters:

ERP	0.50 kW
Polarization	vertical
Offset	3

5 Conclusion

The procedure for new transmitter insertion into the existing Plan, as well as the results of simulation with software support developed for the proposed algorithm are presented in this paper. The same procedure can be also applied for other radio communication services using the corresponding plans and technical requirements databases (minimum field strength, protection ratios, etc.). The developed software for field strength calculation can be applied for all radio communication services operating in the frequency band from 30 MHz to 1000 MHz.

It seems possible to use the described procedure also for the modification of proposed effective radiated power for new transmitter. Namely, while evaluating field strength value of interfering signal at the edge of service area associated with existing transmitter, it is possible to determine the extent value compared to permissible level. For this extent, it is possible to reduce effective radiated power of new transmitter. Taking into account all these modifications due to the impact of several existing transmitters, it is possible to construct radiation pattern for new transmitter. It is obviously not always possible, according to such pattern, to form a real antenna system, but it is worthwhile to try.

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